Prepared in cooperation with the
WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION,
OFFICE OF MINING AND RECLAMATION

Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000

Water-Resources Investigations Report 01-4092

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2001

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Multiply	By	To Obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meters (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/ km^2]

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

°C = (°F –32) / 1.8

VERTICAL DATUM

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment for the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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Abstract

The effects of mountaintop removal coal mining and the valley fills created by this mining method in southern West Virginia were investigated by comparing data collected at valley-fill, mined, and unmined sites. Bed material downstream of valley-fill sites had a greater number of particles less than 2 millimeters and a smaller median particle size than the mined and unmined sites. At the 84th percentile of sampled data, however, bed material at each site type had about the same size particles.

Bankfull cross-sectional areas at a riffle section were approximately equal at valley-fill and unmined sites, but not enough time has passed and insufficient streamflows since the land was disturbed may have prevented the stream channel at valley-fill sites from reaching equilibrium. The 90-percent flow durations at valley-fill sites generally were 6-7 times greater than at unmined sites. Some valley-fill sites, however, exhibited streamflows similar to unmined sites, and some unmined sites exhibited streamflows similar to valley-fill sites. Daily streamflows from valley-fill sites generally are greater than daily streamflows from unmined sites during periods of low streamflow. Valley-fill sites have a greater percentage of base-flow and a lower percentage of flow from storm runoff than unmined sites. Water temperatures from a valley-fill site exhibited lower daily fluctuations and seasonal variations than water temperatures from an unmined site.

INTRODUCTION

Increased mechanization of coal mining in West Virginia in recent decades has led to wider-scale use of mountaintop-mining techniques to reach coal seams and the use of valleys to dispose of excess materials, creating what is known as “valley fills.” Mountaintop mining with valley fills in the coal-mining region, southern West Virginia, has changed forested landscapes with layered sedimentary rocks into grass-covered landscapes containing poorly sorted rock fragments with large interconnected spaces. The U.S. Geological Survey (USGS), in cooperation with the West Virginia Department of Environmental Protection, Office of Mining and Reclamation, investigated the stream geomorphology and measured the low streamflow and stream temperature from mined and unmined areas to determine the effects of valley fills upon streams.

Results of this study will be used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). The Mountaintop Mining/Valley Fill EIS will assess the policies, guidance, and decision-making processes of regulatory agencies in order to minimize any adverse environmental effects from this mining practice. Preparation of the EIS is a voluntary effort among the Office of Surface Mining, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Fish and Wildlife, and the West Virginia Department of Environmental Protection (U.S. Environmental Protection Agency, 2001).

This report presents comparisons of streambed materials, stream-channel characteristics, low streamflow, and stream temperature among sites with and without valley fills. A comparison of streambed materials can indicate habitat alteration for stream aquatic organisms if the particle-size distribution shows an appreciable change in the number of small particles. A comparison of stream-channel characteristics can indicate an increase in peak discharges if bankfull area, width, and depth increase. A comparison of stream temperature can indicate possible effects to stream aquatic organisms if the magnitude of annual fluctuations are reduced. A comparison of low streamflow can indicate changes in water quantity and alterations in habitat that can affect the stream aquatic communities. The study area is in the southern coalfields of West Virginia, and results of this study may apply to other areas along the Appalachian Mountains and worldwide with similar geohydrology.

Description of study area

The study area is in the Appalachian Plateaus Physiographic Province of southern West Virginia (fig. 1). It consists of consolidated, mostly noncarbonate sedimentary rocks that dip gently to the northwest. Streams have eroded the rocks forming steep hills with deeply incised valleys that follow a dendritic pattern and have formed uplifted plateaus because of resistant layers of sandstone and shale (Fenneman, 1938; Fenneman and Johnson, 1946; and U.S. Geological Survey, 1970). Most ground water flows primarily in bedding-plane separations beneath valley floors and in slump fractures along the valley walls (Wyrick and Borchers, 1981). Generally, ground-water movement is greater laterally than vertically and decreases with increasing depth to about 100 ft, except in coal seams where equivalent ground water can move at depths greater than 200 feet (Harlow and LeCain, 1993). The climate is primarily continental, with mild summers and cold winters (U.S. Geological Survey, 1991). Mean annual precipitation is about 44 in. (U.S. Department of Commerce, 1960), and a 24-hour precipitation intensity of about 2.75 in. falls on the average of once every two years (U.S. Department of Commerce, 1961).

Background

The demand for low-sulfur coal increased during the 1990s partly because of efforts to reduce harmful emissions from coal-fired power plants. This increase and the application of dragline mining technologies made it economical to extract low-sulfur coal from the southern coalfields of West Virginia. The draglines remove large quantities of material atop and between the low-sulfur coal seams and deposit the material in adjacent valleys. The number of mines using dragline methods has increased affecting the environment. These effects include alterations in streambed material, stream-channel characteristics, low streamflow, and stream temperature.

Many of the changes in the stream environment that potentially result from mountaintop mining affect biological communities in these streams. Changes in sediment transport and deposition, streamflows, and temperature alter the physical and chemical environment to which biological communities are adapted.

Deposition of fine-grained sediment often alters the physical habitat of streams. Changes in the physical habitat used for feeding, reproduction, and cover affect biological communities. Although all stream communities may be affected by habitat change caused by sedimentation, effects to benthic invertebrate and fish communities have been studied most extensively.

Increases in transport and deposition of fine sediments decreases the abundance of invertebrates and invertebrate species (Lemly, 1982; Nutall, 1972). Some taxa, such as the Heptageniid mayfly *Epeorus pleuralis*, prefer a habitat underneath large rocks in cobble substrates. Filling of the spaces underneath the large rocks by fine sediments reduces the availability of this habitat (Minshall, 1967). Some invertebrates are displaced by the loss of this habitat, and other invertebrates must modify behaviors making them more susceptible to predation (Haro and Brusven, 1994). Sedimentation can decrease flow through the stream substrate, decreasing the availability of the stream-substrate habitat, an important refuge for invertebrates during droughts (Richards and Bacon, 1994). Sedimentation can reduce invertebrate feeding efficiency. Malas and Wallace (1977) found that sediments can clog the finely meshed capture nets of the filter feeding caddisfly *Dolophilodes modesta*. Furthermore, sedimentation can reduce the quality of food resources for the benthic community (Graham, 1990).

Sedimentation can reduce or eliminate the abundance of fish and fish species because of the sedimentation effects on the invertebrate communities. Particular fish species that feed upon benthic macroinvertebrates and periphyton may be reduced or eliminated because sedimentation reduces their food sources (Berkman and Rabeni, 1987). Berkman and Rabeni also found that particular fish species requiring clean stony or gravel substrates for spawning may be reduced or elim-

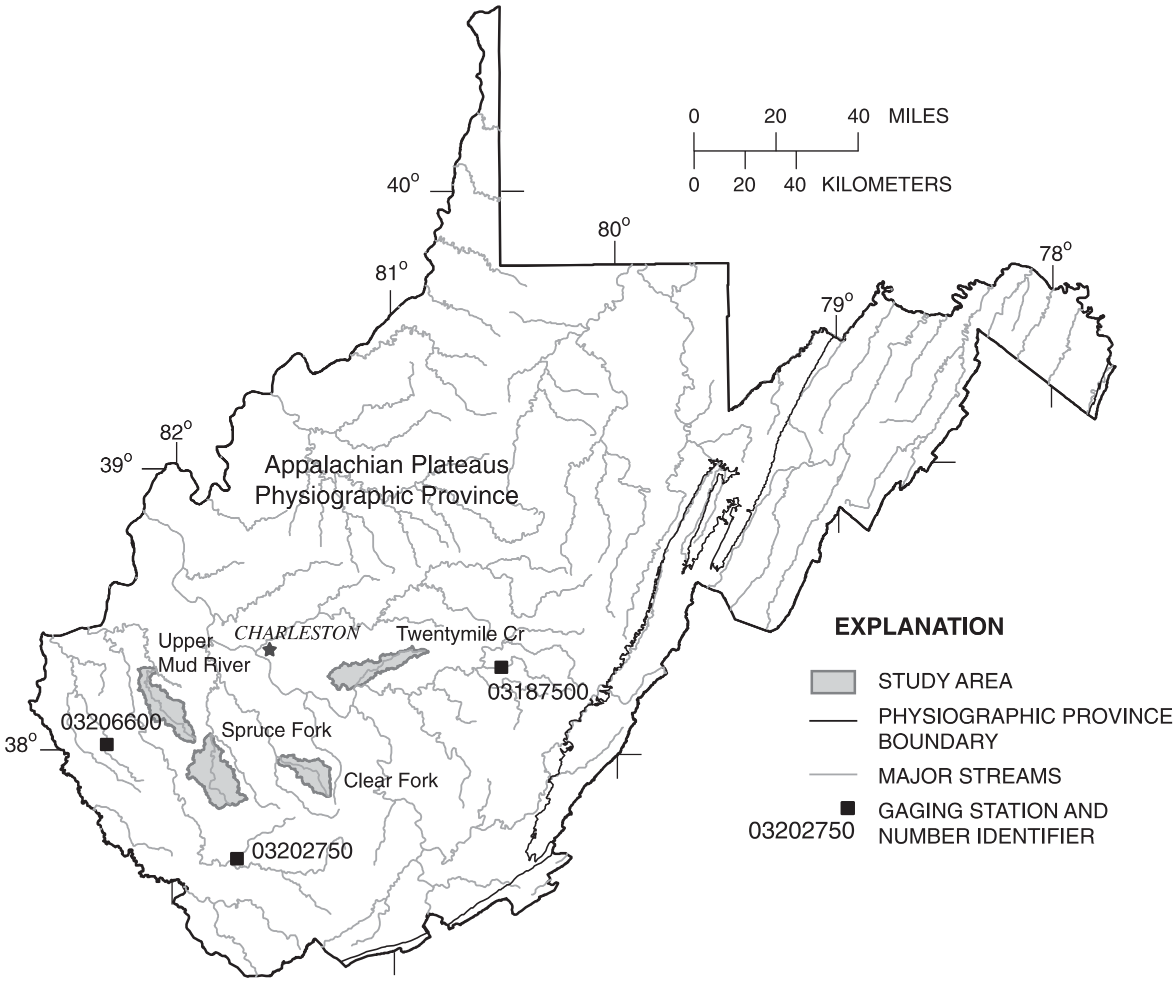

Figure 1. Location of study basins and long-term gaging stations in the coal-mining region of southern West Virginia.

inated because of increased sedimentation. Furthermore, sedimentation can eliminate or reduce deep pool habitats, a habitat providing cooler waters with increased stream depth during summer months (Waters, 1995).

Increases in 90-percent flow duration, the flow that is exceeded 90-percent of the time, and baseflow, the portion of flow the stream receives from ground water, at valley-fill sites can affect benthic invertebrate communities. Streams with valley fills may flow throughout the drought season, although before mining, no-flow periods may have been common. During droughts, invertebrates utilize various drought-survival strategies enabling them to persist until streamflows return (Feminella, 1996; Dietrich and Anderson, 2000). The effects to benthic communities of subtle alterations in streamflow are uncertain because, other than flood or drought effects, little attention has been given to studying the effect of changing streamflow in stream ecology. Increases in baseflow from valley fills can be beneficial because of increases in water availability and waste assimilation. However, increases in baseflow from valley fills can be detrimental because streamflows originating from valley fills can have higher specific conductance than streamflows originating from other settings (Green and others, 2000); thus, eliminating some sensitive species and reducing numbers of tolerant species (Green and others, 2000).

Water temperature affects all aspects of aquatic invertebrate physiology and ecology (Allan, 1995). Timing of crucial life-cycle events such as egg hatching, emergence, and mating relies on thermal cues

(Ward and Stanford, 1982). Temperature controls the growth rate of most species, and interactions among closely related species may be reduced because different responses to temperature segregate the species in time (Ward and Stanford, 1982). Temperature controls the feeding efficiency of invertebrate species along a thermal gradient such that the optimal temperature for assimilation of food often determines the distribution of invertebrate species. Furthermore, temperature changes can increase or decrease algal food production, thereby affecting all higher levels in the food chain (Ward and Stanford, 1982). The annual range of temperatures can also affect the invertebrate communities. An increase in the annual range of temperature, within limits, can increase the number of invertebrates species and the abundance of many species in a stream. A decrease in the annual range of temperature, whether from natural or human factors, can decrease the number of species in a stream (Ward and Stanford, 1982).

DATA COLLECTION

Stream geomorphology and low streamflow measurements were made at a network of 54 small stream sites with drainage areas of 26 to 1,527 acres (fig. 2). The 54 sites were chosen from a larger group of about 120 sites with similar drainage areas. A team of agencies determined the 120 sites as sample locations. The 120 sites were located in five basins, and the sites had an identified land use of either unmined, mined, or valley fill. Unmined sites were those with no evidence of previous coal mining in the tributary watersheds. Mined sites represent watersheds where coal has been mined but where no valley fills were constructed. Valley-fill sites were in tributary watersheds where both previous mining and valley fills were present. In general, the valley-fill sites represent recent or larger mining operations, and the mined sites represent older or smaller operations.

Two sites (station numbers MT67 and MT68B) were combined to make one of the 54 sites because particle size could not be measured on the individual stream reaches (fig. 2b). The subset of 54 sites was selected throughout four of the five basins where the USGS had active short-term (data collected for less than 10 years) streamflow-gaging stations: Unnamed Tributary to Ballard Fork near Mud (03204205), Spring Branch near Mud (03204210), and Ballard Fork near Mud (03204215) in the Upper (upstream of Middle Fork) Mud River Basin, (fig. 2a); Clear Fork at Whitesville (03198350) in the Clear Fork Basin (fig. 2b); Twentymile Creek at Vaughan (03192200) in the Twentymile Creek Basin (fig. 2c); and, Spruce Fork at Sharples (03198690) in the Spruce Fork Basin (fig. 2d).

Continuous streamflow and stream temperature were measured at two USGS streamflow-gaging stations in the Upper Mud River Basin, Unnamed Tributary to Ballard Fork near Mud (03204205) and Spring Branch near Mud (03204210). Continuous data are collected at time intervals that accurately represent the changes among individual values. Continuous streamflow data were collected at three long-term (data collected for ten years or longer) USGS gaging stations (fig. 1): Cranberry River near Richwood (03187500), Clear Fork at Clear Fork (03202750), and East Fork Twelvepole Creek near Dunlow (03206600).

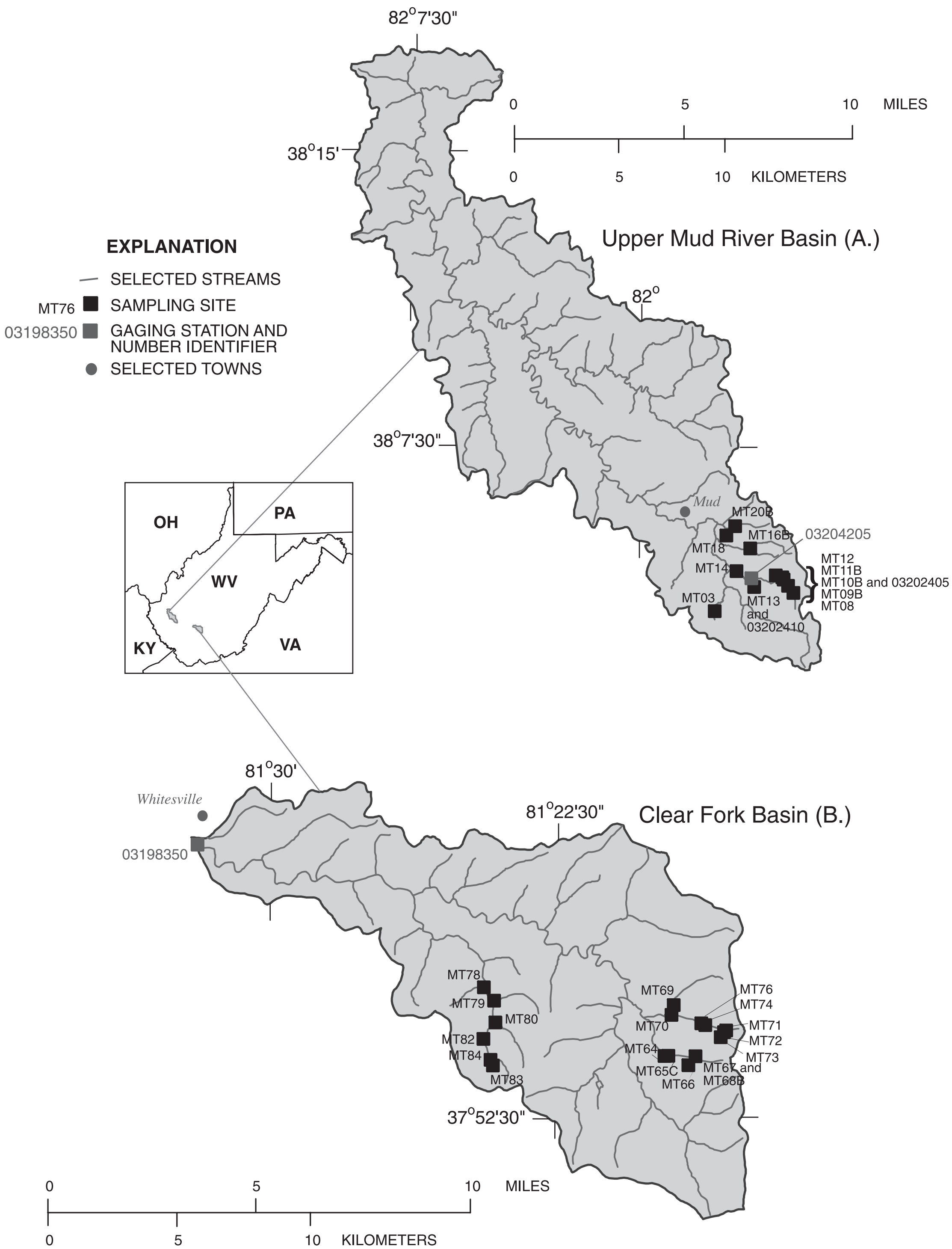

Figure 2A-B. Upper Mud River Basin (A.), Clear Fork Basin (B.), short-term gaging stations, and small-stream sampling sites in the coal-mining region of southern West Virginia.

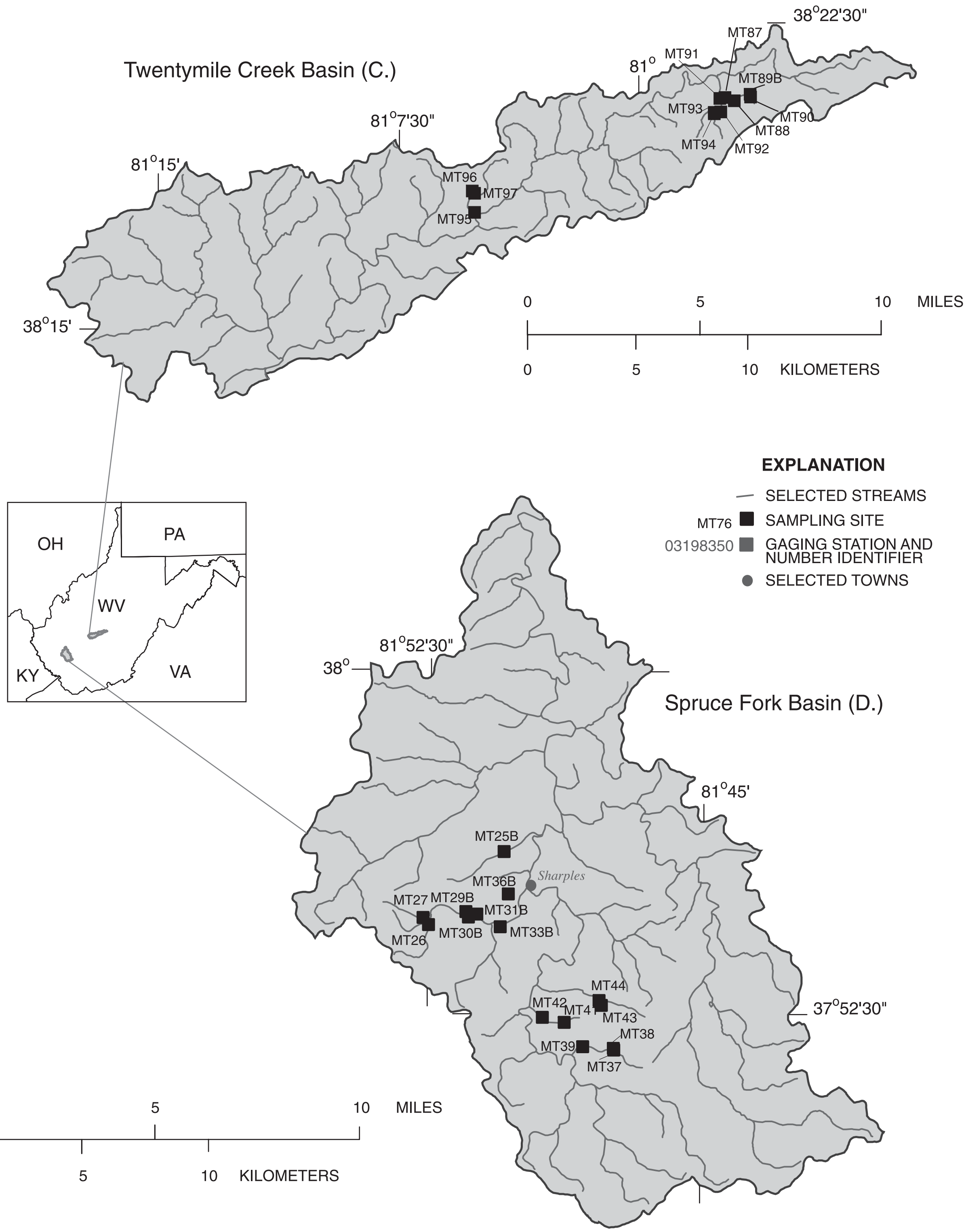

Figure 2C-D. Twentymile Creek Basin (C.), Spruce Fork Basin (D.), short term gaging stations, and small-stream sampling sites in the coal-mining region of southern West Virginia.

Geomorphology

Bed material and bankfull channel characteristics were measured at the 54 sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins (fig. 2). Bankfull is the stream stage and discharge that forms the stream channel. Bankfull discharge transports the maximum amount of sediments over time resulting in bankfull-channel characteristics representative of the watershed (Rosgen, 1996).

Methods described by Wolman (1954) were modified and used to make a quantitative analysis of the distribution of particle sizes on the streambed in this study. The method required measuring the size of up to 100 particles from each stream. Collecting particle-size information from multiple cross sections with a mixture of geomorphic features (such as riffles, pools, and runs) was desired, but at some sites a pool-and-riffle pattern was not available or the streams were too narrow (less than 10 ft). The method presented by Wolman, therefore, was modified to collect pebbles from a mixture of geomorphic features on narrow streams. Streambed-particle sizes were surveyed between October 25 and November 10, 1999 (table 4, located at the end of this report) using the following method:

(1) Begin the pebble count at bankfull elevation on the left bank at the upstream boundary of the stream reach and proceed downstream toward the right bank. Proceed at a 45-degree angle (or less for short reaches) with a line along the center of streamflow (or center of channel if the center of streamflow is not apparent) to the bankfull elevation on the right bank. Proceed downstream from right bank to left bank and left bank to right bank until 60-100 pebbles are collected or until arriving at the end of the stream reach.

(2) Proceed one step at a time, with each step constituting a sampling point.

(3) At each step, reach down to the tip of your boot and, with your finger extended, pick up the first pebble touched by the extended finger;

(4) To reduce sampling bias, look across and not down at the channel bottom when taking steps or retrieving bed material; and,

(5) As you retrieve each pebble, measure the intermediate axis. If the intermediate axis cannot be determined easily, measure the long diameter and the short diameter of the pebble, and determine the average of the two numbers.

Bankfull channel characteristics were surveyed between August 31 and November 9, 2000 (table 4). A cross section was selected in a riffle where effects of exceptional features such as a large (relative to the stream size) rock, cliff, or fallen tree were minimal. The bankfull channel was located using techniques that include identifying bankfull indicators such as changes in bank slope, vegetation, and sediments. The maximum depth, width, and cross-sectional area of the bankfull channel were determined.

Low streamflow measurements

Discharges at the 54 sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins (fig. 2) were measured four times during low streamflow (table 5, located at the end of this report) using methods described by Rantz and others, 1982. The four measurement periods were October 25 through November 10, 1999; June 6-9, 2000; August 16-21, 2000; and August 31 through November 9, 2000.

Continuous streamflow and stream temperature

The USGS collects continuous streamflow data at selected locations, provides historic and real-time data at http://www.usgs.gov/ (real-time data are not available for all stations), and publishes data annually (see for example, Ward and others, 2000). Continuous streamflow data are collected following procedures described by Rantz and others, 1982. Streamflow data were collected at two gaging stations where temperature data also were collected. Streamflow data necessary to determine reliable low streamflow statistics for this study required a minimum of 10 years of unregulated continuous record. Data from continuous streamflow-gaging stations with drainage areas approximately equal to those of the 54 sites was preferred, but no stations were available with 10 years of record in the current network of gages with drainage areas as small as the 54 sites. Streamflow-gaging stations in the study area at the time of this study (1999-2000) that had been operating for a minimum of 10 years drained much greater areas: Cranberry River near Richwood (03187500), 80.4 mi^2; Clear Fork at Clear Fork (03202750), 126 mi^2; and, East Fork Twelvepole Creek near Dunlow (03206600), 38.5 mi^2.

Continuous stream temperature was measured at two USGS streamflow-gaging stations established in Ballard Fork of the Upper Mud River Basin in November 1999. The two stations are located near two of the 54 sites (fig. 2a). The station Unnamed Tributary to Ballard Fork near Mud (03202405) is near sample site MT10B, about 400 feet downstream of a valley fill. The station Spring Branch near Mud (03202410) is near sample site MT13, which drains an unmined basin. Installation of the temperature monitors followed manufacturer specifications and procedures described by Wilde and others (1998).

STREAM GEOMORPHOLOGY

Stream geomorphology was analyzed using measurements of bed materials and channel characteristics. Stream geomorphology for unmined, mined, and valley-fill sites are compared.

Bed material

Bed material data were studied using particle sizes of the median, 84th percentile, and percentage less than 2 millimeters. The 84th percentile is an arbitrary particle size equal to two standard deviations larger than the mean size, assuming a normal distribution. The particle size of the 84th percentile has been related to stream roughness, and particles greater than or equal to the 84th percentile can be considered as large particles (Leopold and others, 1995). Particle sizes less than 2 millimeters can be considered as small.

The distribution (median, 84th percentile, and percentage of particles less than 2 millimeters) of particle sizes among unmined sites located within an individual basin are similar (table 4). The distribution of particle sizes for unmined sites among all basins, however, may or may not be similar. Particle sizes from streams draining unmined areas in Spruce Fork and Clear Fork have a similar distribution, but these particle-size distributions are different from those of streams draining unmined areas of both Upper Mud River and Twentymile Creek. The similar and dissimilar particle-size distributions among basins indicate that natural factors, such as localized geology and land slope, may have some affect on particle sizes.

The bed material of mined and unmined sites can have similar distributions of particle sizes when the land surface of the mined site is not appreciably disturbed, and the bed material of mined and valley-fill sites have similar distributions of particle sizes when the land surface of the mined site is disturbed. For example, streams at sites MT82, MT83, and MT84 (table 4), located on and tributary to Sycamore Creek in the Clear Fork Basin, drain areas of approximately the same size. The land upstream of MT82 and MT84 is mined. The land upstream of MT83 is unmined. The percentage of particles less than 2 millimeters at site MT82 (mined) is about three times the percentage of particles less than 2 millimeters at site MT83 (unmined). Additionally, the median particle size at site MT82 (mined) is about 100 millimeters smaller than the median particle size for site MT83 (unmined). Particle-size distributions at the mined site MT84, however, are similar to those at the unmined site.

Data for Spruce Fork and Clear Fork were combined on the basis of the assumption that the similar distributions of particle sizes between the basins indicated that the same natural factors, such as localized geology and land slope, were affecting the basins. The combined basins provided 8 unmined sites, 8 mined sites, and 14 valley-fill sites for further analysis. The minimum, 75th percentile, median, 25th percentile, and maximum particle sizes with outliers indicated as horizontal lines are shown in box plots (fig. 3). Particle sizes less than 2 millimeters are analyzed as equal to 2 millimeters. Valley-fill sites have a greater number of particles less than 2 millimeters, a smaller median particle size (11 sites out of the total 14 sites have median particle sizes less than 2 millimeters), and about the same 84th-percentile particle size as the mined and unmined sites (fig. 3). The percentage of particle sizes less than 2 millimeters increases appreciably at the valley-fill sites compared to the mined and unmined sites.

Data for Upper Mud River and Twentymile Creek were insufficient for analysis similar to that done with the combination of Spruce Fork and Clear Fork data. There are a sufficient number of valley fill sites (8) in the Upper Mud River Basin, but there are no mined sites and only three unmined sites. A sufficient number of unmined sites (7) are available in the Twentymile Creek Basin, but only one mined site and three valley-fill sites are available.

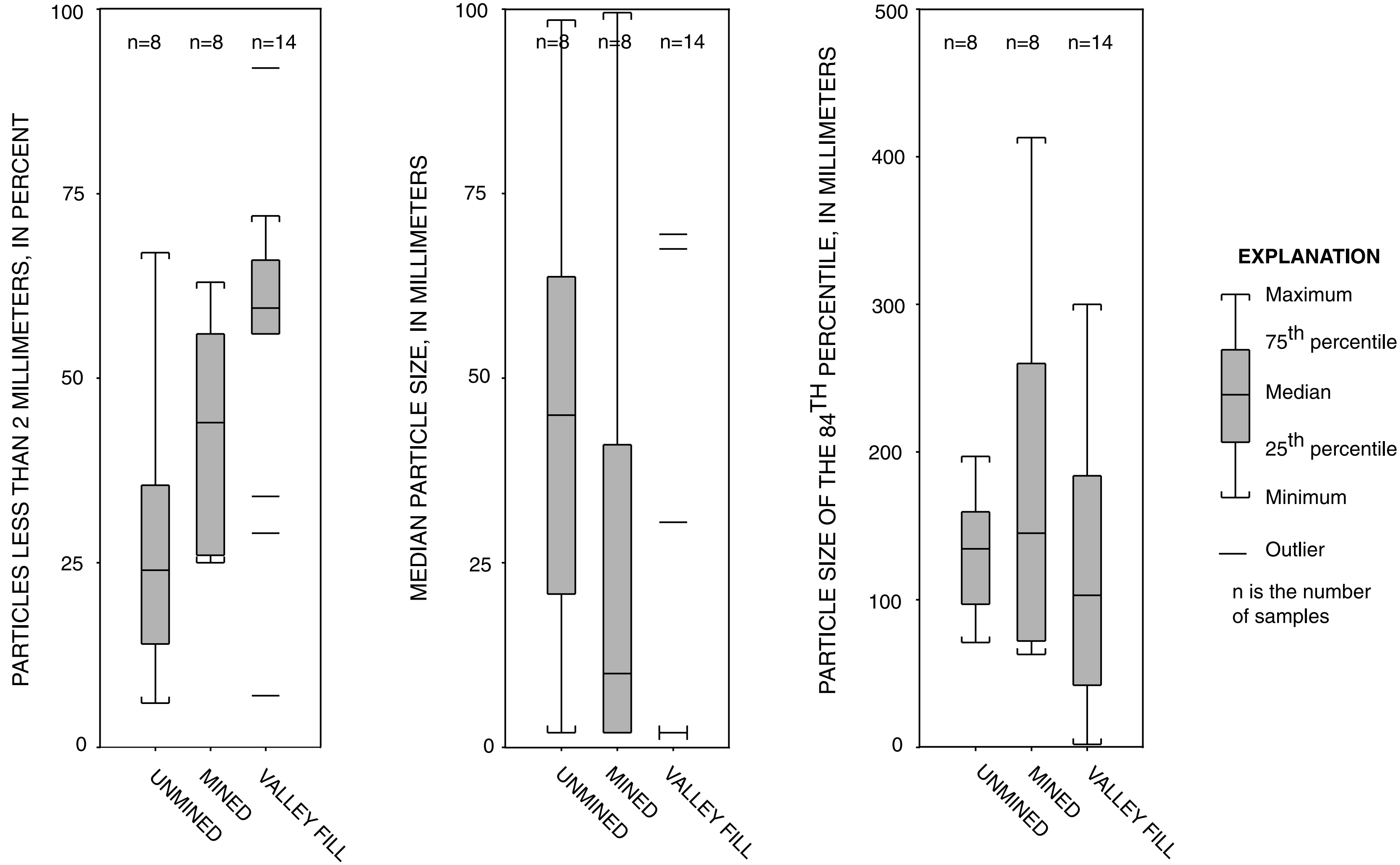

Figure 3. Distributions of particles less than 2 millimeters, median particle size, and particle size of the 84th percentile, Spruce Fork and Clear Fork Basins in the coal-mining region of southern West Virginia.

Sites with an increase in the percentage of particles less than 2 millimeters could return to the particle-size distributions that were present before the land disturbance. A sediment-load study (Ward and Appel, 1988) in relation to highway construction in southern West Virginia indicated that sediment loads decreased after revegetation and stabilization of the disturbed land. The report also indicated a trend of decreasing magnitudes of sediment loads, but the time required for the sediment loads to return to magnitudes of the pre-construction loads was not measured. Particle-size distributions measured in this study could follow a similar trend as the decreasing sediment loads in the previous report and return to the pre-disturbed distributions.

Channel characteristics

The maximum depth, width, and cross-sectional area of the bankfull channel at a riffle section were compared among valley-fill and unmined sites. Mined sites were not considered in this analysis because there were only nine, which is an insufficient number of sites to develop a regression curve. Comparisons among maximum depths, maximum widths, and drainage areas did not indicate any difference between valley-fill and unmined sites. Comparisons among cross-sectional areas and drainage areas (fig. 4) show the similarity between the valley-fill and unmined sites. The linear regression equation for the valley-fill sites (R-squared = 0.48; standard error = 47 percent) is

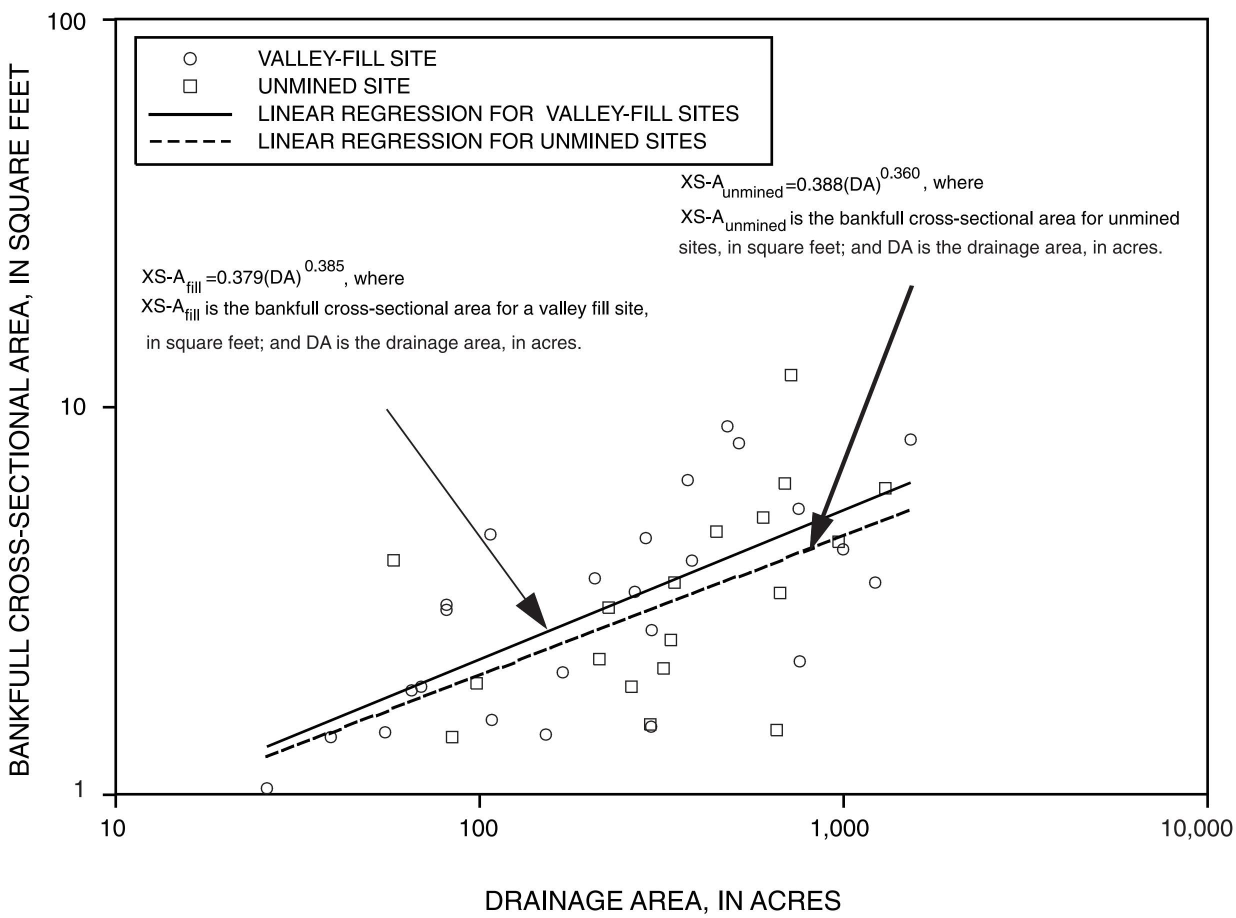

Figure 4. Comparisons among bankfull cross-sectional areas and drainage areas for valley-fill and unmined sites in the coal-mining region of southern West Virginia.

$$XS\text{-}A_{fill} = 0.379\ (DA)^{0.385},$$

where

$XS\text{-}A_{fill}$ is the bankfull cross-sectional area for a valley-fill site, in square feet;

and

DA is the drainage area, in acres.

The linear regression equation for the unmined sites (R-squared = 0.27; standard error = 54 percent) is

$$XS\text{-}A_{unmined} = 0.388\ (DA)^{0.360},$$

where

$XS\text{-}A_{unmined}$ is the bankfull cross-sectional area for unmined sites, in square feet;

and

DA is the drainage area, in acres.

The approximately equal bankfull cross-sectional areas of valley-fill and unmined sites suggests the bankfull discharges between the two groups are approximately equal. This conclusion may be inaccurate if bankfull indicators are not representative of land-use changes. Bankfull indicators at valley-fill sites may be biased toward the pre-disturbed condition (an unmined condition) if the elapsed time and peak streamflows since the land was disturbed have been insufficient to bring the channel (thus, the bankfull indicators) to equilibrium.

LOW STREAMFLOW CHARACTERISTICS

Low streamflow characteristics were investigated by comparing 90-percent flow durations (the streamflow expected to be equalled or exceeded at the site 90 percent of the time), daily streamflow records, base-streamflows (streamflow from ground-water discharge), and stormflows (streamflow from over-land runoff) among all valley-fill and unmined sites.

Ward and others (2000) published the 90-percent flow durations for the selected continuous streamflow-gaging stations (table 1). The discharge measurements made at the 54 sites were compared to concurrent discharges at the continuous streamflow stations. These data were used to estimate the 90-percent flow duration at the 54 sites (table 4), using methods described by Riggs (1972).

Low streamflows in relation to drainage area were compared among all valley-fill and unmined sites (fig. 5). Mined sites were not considered in this analysis because only 9 sites were available, which is an insufficient number of sites to develop a regression curve. Sites with 90-percent flow durations of no streamflow were omitted (six sites), because the data were $\log_{10}$ transformed. The valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5). The linear regression equation for the valley-fill sites (R-squared = 0.60; standard error = 115 percent) is

Table 1. Low-streamflow statistics at long-term gaging stations in the coal-mining region of southern West Virginia

Station number	Station name	90-percent flow duration, in cubic feet per second
03187500	Cranberry River near Richwood	16
03202750	Clear Fork at Clear Fork	12
03206600	East Fork Twelvepole Creek near Dunlow	1.3

$$D90_{fill} = 0.000161 \, (DA)^{1.098},$$

where

$D90_{fill}$ is the 90-percent flow duration for a valley-fill site, in cubic feet per second;

and

DA is the drainage area, in acres.

The linear regression equation for the unmined sites (R-squared = 0.29; standard error = 155 percent) is

$$D90_{unmined} = 0.0000209 \, (DA)^{1.129},$$

where

$D90_{unmined}$ is the 90-percent flow duration for an unmined site, in cubic feet per second; and

DA is the drainage area, in acres.

Three of the valley-fill sites (MT74, MT87, and the combination of MT67 and MT68B) exhibited 90-percent flow durations similar to those of unmined sites, and three of the unmined sites (MT41, MT92, and MT97) exhibited 90-percent flow durations similar to those of valley-fill sites (fig. 5). The site MT41 is on Oldhouse Branch in the Spruce Fork Basin. Another site on Oldhouse Branch, MT42, has a larger drainage area and smaller 90-percent flow duration than MT41. Field observations indicated some of the streamflow measurements from MT41 were made where the streambed was a rock outcrop. These measurements at the rock outcrop suggest it restricts ground-water flow, and the outcrop was forcing water to the surface into the stream. The water forced to the surface and into the stream may have produced a greater discharge than typically is at an unmined site with that drainage area. Other unmined sites that exhibit 90-percent flow durations similar to 90-percent flow durations from valley-fill sites may have similar field conditions. This conclusion, however, is speculative and not definitive.

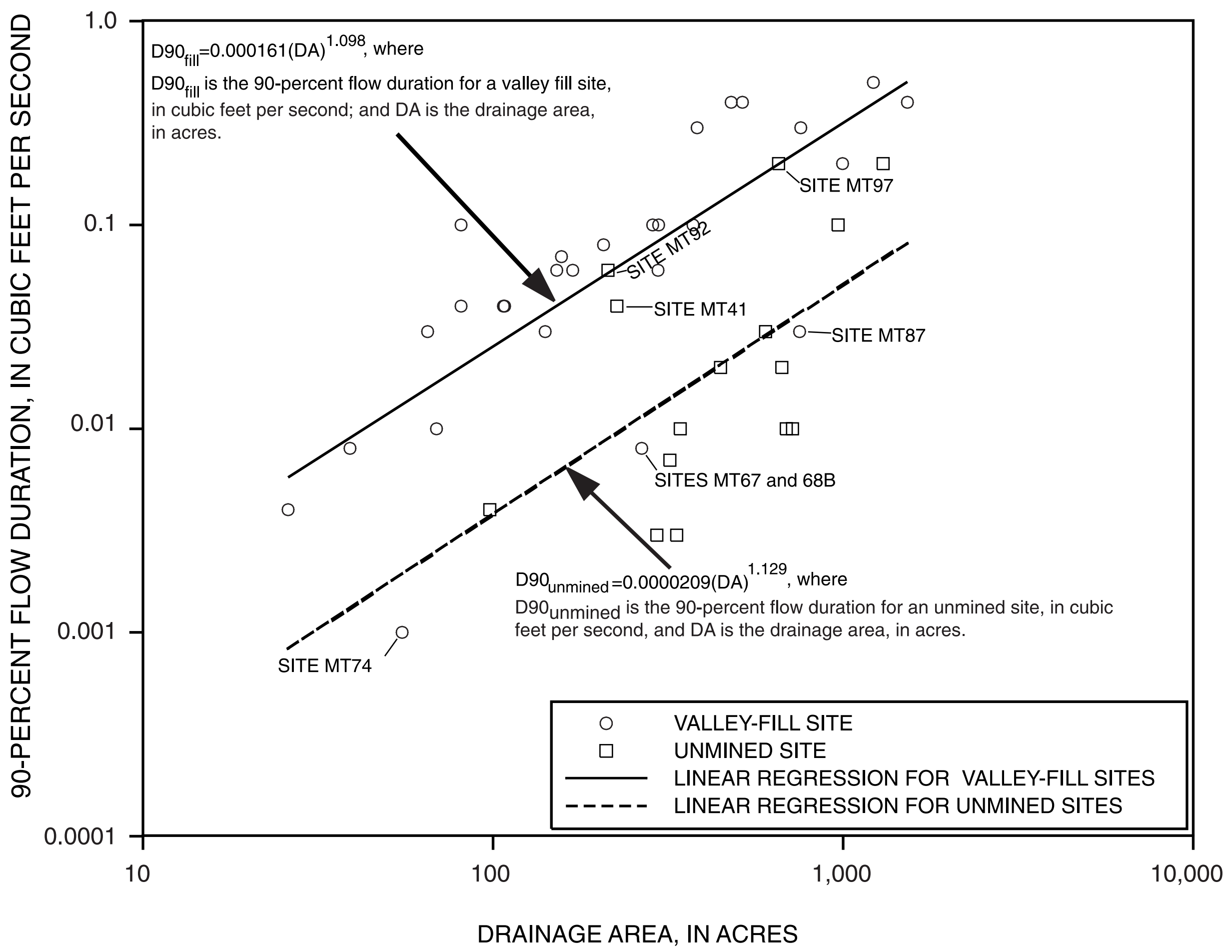

Figure 5. Comparisons among the 90-percent flow durations and drainage areas for valley-fill and unmined sites in the coal-mining region of southern West Virginia.

Valley-fill sites exhibiting 90-percent flow durations similar to unmined sites suggest the fill is not retaining water, as is typical of other fills. Water may not be retained because the fill is relatively small compared to the rest of the drainage area or because of some difference in the design of the fill, but data collected for this study are insufficient to determine a specific cause.

Daily streamflows determined for the valley-fill site, Unnamed Tributary to Ballard Fork near Mud (03202405), and the unmined site, Spring Branch near Mud (03202410), for the period December 1999 through November 2000 are presented in tables 2 and 3, respectively. Spring Branch had no streamflow for several days in October and November, but Unnamed Tributary to Ballard Fork had streamflow for the entire period. Greater streamflows may be expected at Spring Branch than at Unnamed Tributary to Ballard Fork for these days in October and November because the drainage area at Spring Branch (0.53 mi^2) is 2.8 times greater than the drainage area at Unnamed Tributary to Ballard Fork (0.19 mi^2). The most probable reason that streamflow is not greater at Spring Branch than at Unnamed Tributary to Ballard Fork is because Unnamed Tributary to Ballard Fork is a valley-fill site, and the valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5).

The daily streamflow data from Spring Branch and Unnamed Tributary to Ballard Fork gaging stations were analyzed using a technique of streamflow partitioning. Streamflow partitioning separates streamflow data into estimates of base-streamflow and stormflow components using the Rorabaugh streamflow model (Rutledge, 1998). For this report, streamflow data were partitioned for the period December 1999 through November 2000. The estimated unit-mean base streamflow was 0.98 cubic foot per second per square mile of drainage area [$(ft^3/s)/mi^2$] for Unnamed Tributary to Ballard Fork and 0.42 $(ft^3/s)/mi^2$ for Spring Branch. Streamflows were about 84-percent base streamflow and 16-percent stormflow for Unnamed Tributary to Ballard Fork, and streamflows were about 59-percent base streamflow and 41-percent stormflow for Spring Branch. The most probable reason the unit-mean base streamflow and percentage of base streamflow are greater for Unnamed Tributary to Ballard Fork than Spring Branch is because Unnamed Tributary to Ballard Fork is a valley-fill site, and the valley-fill sites can have about a 6-7 times greater 90-percent flow duration than unmined sites (fig. 5).

STREAM TEMPERATURE

Daily water-temperature data measured at Unnamed Tributary to Ballard Fork near Mud (03202405) and at Spring Branch near Mud (03202410), for the period December 1999 through November 2000, are presented in tables 6 and 7, respectively (located at the end of this report). The temperature monitor at Unnamed Tributary to Ballard Fork is approximately 400 ft. downstream from a valley fill. The daily fluctuations of temperatures at Unnamed Tributary to Ballard Fork are less than the daily fluctuations at Spring Branch. The minimum water temperature observed at Unnamed Tributary to Ballard Fork was 3.3°C on January 28, 2000, which indicated above freezing conditions. The minimum water temperature observed at Spring Branch was –2.4°C on January 28, 2000, which probably indicated frozen water conditions. The minimum water temperatures at Unnamed Tributary to Ballard Fork and Spring Branch differ because water at Unnamed Tributary to Ballard Fork was mixed with warmer water discharging from the valley fill. The water temperature at Unnamed Tributary to Ballard Fork showed a lesser seasonal range than the seasonal range observed at Spring Branch. The daily-mean water temperature at Unnamed Tributary to Ballard Fork was greater than the daily-mean water temperature at Spring Branch during winter, and the daily-mean water temperature at Unnamed Tributary to Ballard Fork was less than the daily-mean water temperature at Spring Branch during summer (fig. 6).

Table 2. Daily mean discharges in cubic feet per second, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia

[e, estimated; --, no value; Acre-ft, quantity of water required to cover 1 acre to a depth of 1 foot; CFSM, cubic foot per second per square mile; In., depth to which the drainage area would be covered by the indicated runoff]

Day	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1	0.27	0.26	e0.22	0.31	0.10	0.20	0.28	e0.21	0.20	0.11	0.11	0.12
2	.23	.25	e.20	.29	.10	.20	.25	e.21	.19	.12	.10	.11
3	.20	.27	e.19	.26	.12	.19	.22	e.24	.19	.11	.10	.13
4	.20	.31	e.18	.26	.32	.17	.20	e.27	.17	.13	.10	.14
5	.19	.27	e.17	.25	.37	.16	.17	e.26	.15	.13	.10	.13
6	.20	.28	e.17	.25	.31	.15	.16	e.24	.15	.12	.10	.12
7	.17	.26	e.17	.18	.26	.14	.15	.22	.17	.11	.10	.12
8	.14	.26	e.16	.15	.30	.14	.13	.21	.23	.11	.10	.09
9	.14	.25	.16	.13	.30	.13	.12	.19	.34	.11	.10	.10
10	.17	.26	.15	.11	.26	.13	.11	.28	.54	.15	.10	.10
11	.18	e.25	.17	.21	.24	.13	.11	.55	.51	.17	.10	.10
12	.17	e.24	.16	.25	.21	.11	.11	.53	.40	.19	.10	.10
13	.22	e.23	.17	.25	.19	.13	.10	.43	.33	.16	.10	.10
14	1.3	e.22	.59	.20	.18	.10	.10	.41	.26	.14	.10	.10
15	.99	e.21	.53	.17	.17	.10	.11	.52	.24	.12	.10	.09
16	.70	e.21	.42	.14	.15	.10	.10	.51	.21	.11	.10	.09
17	.52	e.21	.32	.15	.17	.10	.21	.40	.20	.11	.10	.09
18	.43	e.21	.59	.15	.19	.09	.41	.34	.19	.11	.11	.09
19	.37	e.21	e1.8	.15	.18	.10	e.41	.34	.19	.11	.11	.09
20	.34	e.21	e1.1	.16	.17	.09	e.42	.31	.18	.11	.11	.09
21	.30	e.21	.77	.20	.19	.10	e.58	.31	.17	.11	.11	.09
22	.32	e.22	.58	.21	.22	.09	e.58	.28	.15	.11	.10	.09
23	.34	e.23	.48	.18	.21	.11	e.46	.25	.15	.10	.11	.09
24	.31	e.24	.42	.16	.23	.10	e.32	.23	.15	.10	.11	.10
25	.31	e.24	.38	.13	.35	.09	e.32	.22	.15	.14	.11	.10
26	.30	e.22	.34	.13	.39	.09	e.30	.21	.15	.14	.11	.10
27	.28	e.20	.35	.12	.34	.36	e.28	.19	.15	.15	.12	.10
28	.27	e.20	.32	.14	.29	.90	e.29	.19	.15	.13	.14	.10
29	.27	e.22	.31	.13	.25	1.2	e.26	.20	.15	.11	.14	.10
30	.26	e.25	--	.11	.21	.49	e.23	.19	.14	.11	.13	.10
31	.26	e.24	--	.11	--	.34	--	.19	.13	--	.13	--
Total	10.35	7.34	11.57	5.64	6.97	6.53	7.49	9.13	6.68	3.73	3.35	3.07
Mean	.33	.24	.40	.18	.23	.21	.25	.29	.22	.12	.11	.10
Maximum	1.3	.31	1.8	.31	.39	1.2	.58	.55	.54	.19	.14	.14
Minimum	.14	.20	.15	.11	.10	.09	.10	.19	.13	.10	.10	.09
Acre-ft	21	15	23	11	14	13	15	18	13	7.4	6.6	6.1
CFSM	1.76	1.25	2.10	.96	1.22	1.11	1.31	1.55	1.13	.65	.57	.54
In.	2.03	1.44	2.27	1.10	1.36	1.28	1.47	1.79	1.31	.73	.66	.60

Total=81.85	Mean=0.22	Maximum=1.8	Minimum=0.09	Total Acre-ft=162	Total CFSM=1.18	Total In.=16.03

Table 3. Daily mean discharges in cubic feet per second, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia

[e, estimated; --, no value; Acre-ft, quantity of water required to cover 1 acre to a depth of 1 foot; CFSM, cubic foot per second per square mile; In., depth in inches to which the drainage area would be covered by the indicated runoff]

Day	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1	0.13	0.11	0.12	0.35	0.31	0.47	0.25	0.12	0.18	0.09	0.00	0.07
2	.13	.10	.12	.32	.31	.43	.20	.10	.15	.08	.00	.00
3	.12	.11	.13	.30	e.6	.34	.16	.13	.11	.08	.01	.01
4	.11	.18	.15	.29	e3.1	.29	.13	.17	.10	.09	.01	.02
5	.11	.14	.14	.27	e2.1	.26	.12	.13	.09	.07	.01	.05
6	.12	.14	.14	.25	e1.6	.23	.10	.11	.08	.08	.01	.07
7	.10	.14	.15	.25	e1.1	.21	.09	.09	.14	.07	.01	.02
8	.09	.14	.16	.26	e1.6	.18	.07	.07	.30	.08	.00	.00
9	.09	.17	.17	.30	e1.5	.16	.06	.07	.32	.06	.01	.03
10	.20	.18	.19	.26	e1.4	.14	.05	.35	.64	.32	.03	.08
11	.16	.17	.23	.53	e1.2	.11	.04	.87	.33	.10	.00	.03
12	.15	.15	.23	.92	e1.1	.09	.03	.44	.24	.03	.01	.02
13	.29	.14	.25	.90	e.9	.18	.03	.29	.20	.02	.02	.03
14	4.8	.12	2.2	.79	.67	.11	.04	.39	.16	.02	.03	.04
15	1.1	.12	1.4	.66	.60	.08	.11	.36	.13	.02	.00	.04
16	.54	.13	.95	.64	.53	.07	.06	.33	.12	.01	.01	.04
17	.37	.12	.62	.73	.55	.07	.29	.28	.12	.01	.01	.06
18	.29	.12	2.5	.68	.51	.06	.37	.22	.18	.01	.03	.08
19	.24	.12	e14	.68	.49	.20	.37	.36	.13	.01	.00	.10
20	.22	.13	e3.5	.74	.48	.20	.31	.36	.12	.01	.01	.10
21	.18	.11	e1.7	.95	.60	.13	1.8	.30	.12	e.01	.01	.11
22	.17	.10	e1	.94	.64	.10	6.3	.25	.11	e.01	.01	.13
23	.15	.11	.68	.89	.70	.27	1.1	.21	.11	e.01	.02	.14
24	.14	.11	.59	.76	.77	.17	.48	.20	.13	e.01	.02	.17
25	.12	.10	.49	.66	1.5	.13	.32	.17	.10	e.01	.00	.07
26	.13	.10	.41	.59	1.8	.10	.25	.14	.10	e.01	.01	.04
27	.12	.09	.43	.54	1.4	2.6	.23	.11	.14	e.01	.01	.04
28	.12	.08	.38	.49	1.0	2.0	.25	.12	.10	e.01	.01	.04
29	.11	.10	.35	.41	.76	.88	.20	.13	.09	e.01	.01	.05
30	.11	.15	--	.37	.56	.53	.16	.16	.08	e.01	.03	.08
31	.11	.13	--	.33	--	.34	--	.12	.08	--	.06	--
Total	10.82	3.91	33.38	17.05	30.38	11.13	13.97	7.15	5.00	1.36	0.40	1.76
Mean	.35	.13	1.15	.55	1.01	.36	.47	.23	.16	.045	.013	.059
Maximum	4.8	.18	14	.95	3.1	2.6	6.3	.87	.64	.32	.06	.17
Minimum	.09	.08	.12	.25	.31	.06	.03	.07	.08	.01	.00	.00
Acre-ft	21	7.8	66	34	60	22	28	14	9.9	2.7	.8	3.5
CFSM	.66	.24	2.17	1.04	1.91	.68	.88	.44	.30	.09	.02	.11
In.	.76	.27	2.34	1.20	2.13	.78	.98	.50	.35	.10	.03	.12

Total=136.31	Mean=0.37	Maximum=14	Minimum=0.00	Total Acre-ft=270	Total CFSM=0.70	Total In.=9.57

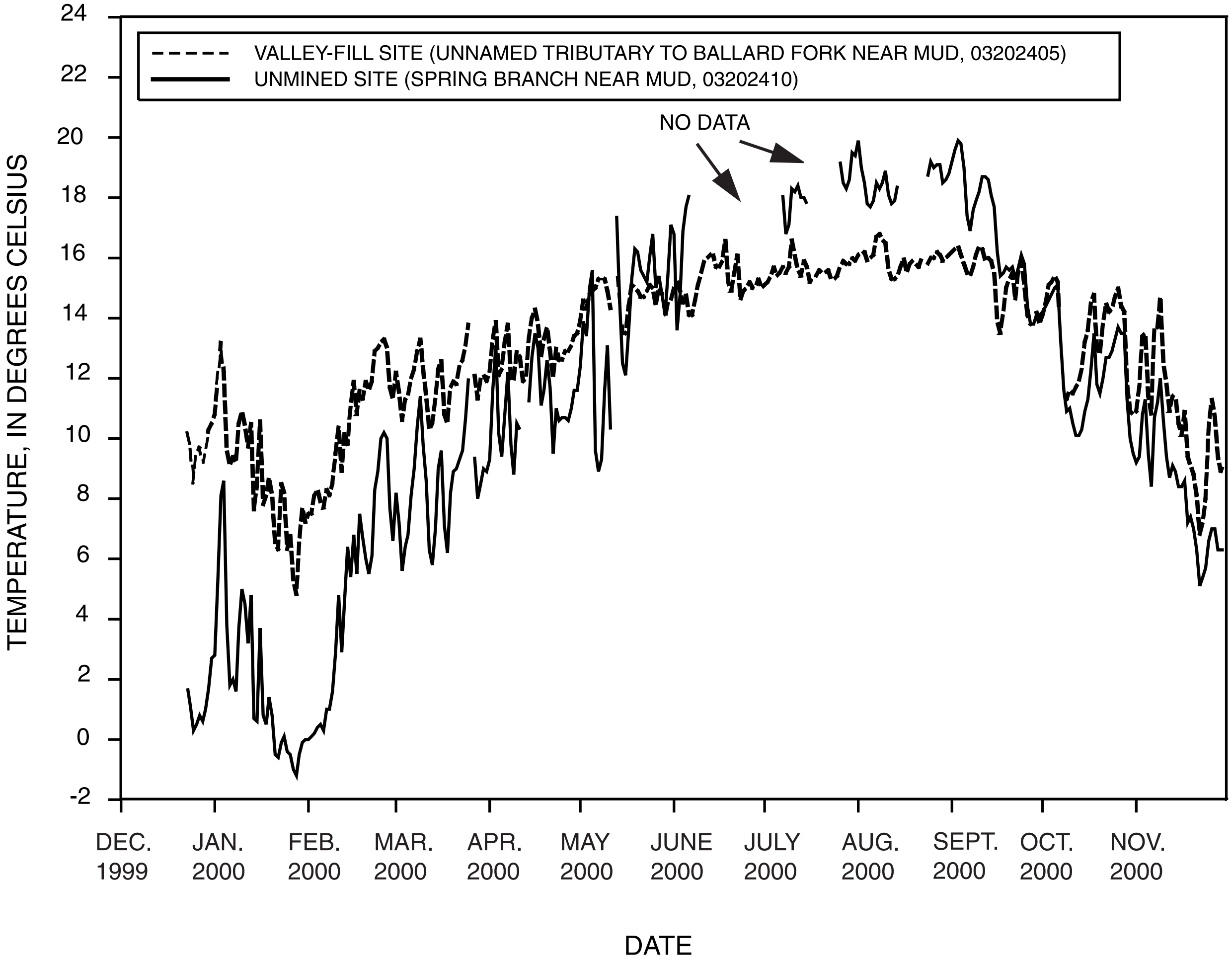

Figure 6. Daily mean water temperatures, December 1999 through November 2000, at a valley-fill and an unmined site in the coal-mining region of southern West Virginia.

SUMMARY

Mining coal by removing mountaintops and disposing of the overburden in valleys, creating valley fills, has changed the landscape in the coal-mining region of southern West Virginia and affected stream geomorphology, low streamflow, and stream temperatures. The USGS, in cooperation with the West Virginia Department of Environmental Protection, Office of Mining and Reclamation, investigated these mining effects by comparing data collected between 1999 and 2000 in four basins at valley-fill, unmined, and mined sites. Information from this study will assist in the preparation of an Environmental Impact Statement to assess the policies, guidance, and decision-making processes of regulatory agencies in order to minimize any adverse environmental effects from this mining practice.

Particle sizes were measured at 54 small stream sites in the Clear Fork, Upper Mud River, Spruce Fork, and Twentymile Creek Basins, using a modification to the procedure described by Wolman (1954). A comparison of all unmined sites indicated that distribution of particle sizes can differ among unmined basins. The different distributions among basins suggests that natural factors may have some effect over particle sizes. Valley-fill sites had a greater number of particles less than 2 millimeters in size, a smaller median particle size, and about the same 84th percentile particle size, as compared to the mined and unmined sites.

Bankfull maximum depth, width, and cross-sectional area at a riffle section were measured at the 54 small-stream sites. No differences in the bankfull measurements could be determined between valley-fill and unmined sites. Bankfull indicators at valley-fill sites

may not represent the valley-fill condition if there has not been enough time and if peak streamflows since the land was disturbed have been insufficient to bring the channel to equilibrium.

Low streamflows were investigated by comparing 90-percent flow durations, daily streamflow records, base-streamflows, and stormflows. Generally, the 90-percent flow durations at valley-fill sites were 6-7 times greater than the 90-percent flow durations at unmined sites. Some valley-fill sites, however, exhibited 90-percent flow durations similar to unmined sites, and some unmined sites exhibited 90-percent flow durations similar to valley-fill sites. Daily streamflows from valley-fill sites generally are greater than daily streamflows from unmined sites during periods of low streamflow. Valley-fill sites have a greater percentage of base-streamflows and lower percentage of stormflows than unmined sites.

Stream temperature was recorded at a valley-fill site and at an unmined site. Water temperatures from a valley-fill site exhibited lower daily fluctuations and lesser seasonal variations than water temperatures from an unmined site. Water temperatures from the valley-fill site were warmer in the winter and cooler in the summer than water temperatures from the unmined site.

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TABLES

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia

[--, no value; <, less than]

Station number	Stream name	Latitude	Longi-tude	Drain-age area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
Clear Fork Basin												
MT64	Buffalo Fork	37°53’58”	81°19’52”	758	Valley fill	0.3	<2	205	62	9.1	0.52	2.21
MT65C	Unnamed tributary to Buffalo Fork	37°53’48”	81°19’38”	65	Valley fill	.03	<2	225	57	5.8	.59	1.86
MT66	Buffalo Fork	37°53’47”	81°19’09”	373	Valley fill	.1	<2	43	56	13.5	.95	6.49
MT67 and	Unnamed tributary to Buffalo Fork	37°53’47”	81°18’55”	46	Valley fill	.008	2	48	70	9.9	.77	3.34
MT68B	Unnamed tributary to Buffalo Fork	37°53’46”	81°18’53”	221	Valley fill							
MT69	Ewing Fork	37°54’50”	81°19’30”	708	Mined	.2	10	145	41	10.5	.57	4.38
MT70	Toney Fork	37°54’38”	81°19’33”	1,221	Valley fill	.5	<2	21	72	6.0	1.04	3.53
MT71	Toney Fork	37°54’19”	81°18’07”	81	Valley fill	.04	<2	176	56	6.0	.85	3.09
MT72	Unnamed tributary to Toney Fork	37°54’17”	81°18’11”	107	Valley fill	.04	30.5	184	34	7.0	.95	4.70
MT73	Toney Fork	37°54’21”	81°18’17”	207	Valley fill	.08	--	--	--	7.0	.80	3.62
MT74	Unnamed tributary to Toney Fork	37°54’25”	81°18’40”	55	Valley fill	.001	67.5	300	29	5.0	.50	1.45
MT76	Reeds Branch	37°54’28”	81°18’46”	296	Valley fill	.06	<2	97	60	4.3	.61	1.50
MT78	Raines Fork	37°55’11”	81°24’26”	524	Mined	0	--	--	--	6.6	.73	3.04

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT79	Davis Fork	37º54’55”	81º24’10”	448	Mined	0.005	41	431	25	11.8	1.41	16.7
MT80	Lem Fork	37º54’28”	81º24’08”	689	Unmined	.01	26.5	142	38	8.4	.76	6.36
MT82	Unnamed tributary to Sycamore Creek	37º54’08”	81º24’26”	294	Mined	0	<2	72	56	8.7	.47	1.48
MT83	Unnamed tributary to Sycamore Creek	37º53’44”	81º24’11”	261	Unmined	0	98.5	197	20	5.5	.63	1.90
MT84	Sycamore Creek	37º53’42”	81º24’15”	222	Mined	0	99.5	217	26	3.8	.75	1.62
Mud River Basin												
MT03	Lukey Fork	38º03’18”	81º57’31”	717	Unmined	.01	<2	164	53	13.0	.93	12.1
MT08	Sally Fork of Ballard Fork	38º03’47”	81º54’58”	98	Unmined	.004	<2	81	61	5.9	.58	1.94
MT09B	Sally Fork of Ballard Fork	38º03’58”	81º55’09”	39	Valley fill	.008	<2	269	59	4.6	.42	1.14
MT10B	Ballard Fork	38º04’08”	81º55’18”	152	Valley fill	.06	<2	<2	95	4.1	.51	1.43
MT11B	Left Fork of Ballard Fork	38º04’11”	81º55’20”	157	Valley fill	.07	<2	<2	86	- -	- -	- -
MT12	Unnamed tributary to Ballard Fork	38º04’10”	81º55’29”	26	Valley fill	.004	<2	<2	87	3.7	.45	1.04
MT13	Spring Branch of Ballard Fork	38º04’02”	81º56’16”	335	Unmined	.003	<2	26	69	6.4	.39	2.51

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT14	Ballard Fork	38º04'20"	81º56'49"	1,527	Valley fill	0.4	<2	42	63	12.7	0.65	8.26
MT16B	Unnamed tributary to Stanley Fork	38º04'55"	81º56'23"	516	Valley fill	.4	<2	8	83	15.3	.74	8.08
MT18	Sugartree Branch	38º05'26"	81º57'04"	479	Valley fill	.4	<2	84	52	12.4	.72	8.93
MT20B	Sugartree Branch	38º05'29"	81º56'53"	383	Valley fill	.3	<2	<2	90	6.0	1.01	4.02
Spruce Fork Basin												
MT25B	Rockhouse Creek	37º56'01"	81º50'26"	997	Valley fill	.2	69.5	149	7	10.4	.80	4.30
MT26	Beech Creek	37º54'25"	81º52'30"	920	Mined	.002	13	260	44	2.9	.95	2.06
MT27	Unnamed tributary to Beech Creek	37º54'34"	81º52'39"	266	Mined	.001	<2	63	53	15.0	1.2	11.6
MT29B	Unnamed tributary to Beech Creek	37º54'42"	81º51'28"	81	Valley fill	.1	<2	<2	92	6.0	1.15	3.00
MT30B	Unnamed tributary to Beech Creek	37º54'35"	81º51'24"	169	Valley fill	.06	<2	16	66	3.2	.90	2.07
MT31B	Unnamed tributary to Beech Creek	37º54'39"	81º51'10"	141	Valley fill	.03	--	--	--	--	--	--
MT33B	Unnamed tributary to Beech Creek	37º54'34"	81º50'39"	69	Valley fill	.01	<2	109	61	4.5	.60	1.90
MT36B	Hurricane Branch	37º55'05"	81º50'18"	286	Valley fill	.1	<2	42	59	8.0	.85	4.60
MT37	White Oak Branch	37º51'42"	81º47'23"	320	Unmined	.007	60.5	127	6	5.9	.69	2.12

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT38	Unnamed tributary to White Oak Branch	37º51'45"	81º47'23"	84	Unmined	0	35.5	147	27	6.2	0.45	1.41
MT39	White Oak Branch	37º51'46"	81º48'14"	669	Unmined	.02	54.5	120	21	11.3	.59	3.32
MT41	Oldhouse Branch	37º52'18"	81º48'44"	226	Unmined	.04	15	71	33	8.6	.58	3.04
MT42	Oldhouse Branch	37º52'24"	81º49'20"	447	Unmined	.02	67	172	8	11.6	.89	4.78
MT43	Pigeonroost Branch	37º52'48"	81º47'46"	470	Mined	.04	<2	103	63	10.6	.88	4.58
MT44	Unnamed tributary to Pigeonroost Branch	37º52'47"	81º47'47"	294	Unmined	.003	<2	74	67	7.2	.33	1.52
Twentymile Creek Basin												
MT87	Neff Fork	38º20'41"	80º57'21"	752	Valley fill	.03	<2	135	61	12.4	.62	5.47
MT88	Unnamed tributary to Neff Fork	38º20'36"	80º57'04"	179	Mined	.07	<2	70	54	7.7	.41	1.46
MT89B	Unnamed tributary to Neff Fork	38º20'45"	80º56'34"	108	Valley fill	.04	42.5	128	34	7.1	.47	1.56
MT90	Neff Fork	38º20'41"	80º56'33"	297	Valley fill	.1	14	164	45	7.9	.52	2.66
MT91	Rader Fork	38º20'39"	80º57'30"	1,302	Unmined	.2	<2	81	79	17.8	.57	6.18
MT92	Unnamed tributary to Radar Fork	38º20'19"	80º57'28"	213	Unmined	.06	34.5	82	28	10.4	.39	2.24
MT93	Laurel Run	38º20'18"	80º57'41"	343	Unmined	.01	<2	146	57	10.1	.65	3.53

Table 4. Low streamflow, particle sizes, and channel characteristics for sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value; <, less than]

Station number	Stream name	Latitude	Longitude	Drainage area, in acres	Mining class	90-percent flow duration, in cubic feet per second	Median particle size, in millimeters	Particle size of the 84th percentile, in millimeters	Particles smaller than 2 millimeters, in percent	Bankfull cross-section width, in feet	Maximum bankfull cross-section depth, in feet	Bankfull cross-section area, in square feet
MT94	Rader Fork	38º20'16"	80º57'41"	601	Unmined	0.03	<2	23	81	12.9	0.69	5.19
MT95	Neil Branch	38º17'51"	81º05'10"	968	Unmined	.1	73.5	184	19	11.6	.59	4.50
MT96	Unnamed tributary to Neil Branch	38º18'22"	81º05'14"	58	Unmined	0	<2	110	65	11.6	.59	4.03
MT97	Neil Branch	38º18'19"	81º05'10"	654	Unmined	.2	52	141	35	6.2	.37	1.47

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
Clear Fork Basin													
MT64	Buffalo Fork	10/27/99	1420	0.249	06/08/00	1100	0.948	08/16/00	1330	0.815	10/16/00	1050	0.403
MT65C	Unnamed tributary to Buffalo Fork	10/27/99	1340	.027	06/08/00	1025	.161	08/16/00	1250	.102	10/16/00	1025	.037
MT66	Buffalo Fork	10/27/99	1225	.146	06/09/00	1128	.338	08/16/00	1115	.050	10/04/00	1610	.370
MT67 and MT68B	Unnamed tributary to Buffalo Fork Unnamed tributary to Buffalo Fork	10/27/99	1135	.008	06/09/00	1455	.446	08/17/00	1150	.338	10/16/00	0940	0.170
MT69	Ewing Fork	10/26/99	1055	.212	06/08/00	1408	.901	08/16/00	1730	.906	10/04/00	1450	7.64
MT70	Toney Fork	10/26/99	1150	.007	06/08/00	1325	.943	08/16/00	1635	.787	10/04/00	1345	.675
MT71	Toney Fork	10/26/99	1505	.042	06/08/00	1156	.063	08/06/00	1430	.046	10/04/00	1015	.088
MT72	Unnamed tributary to Toney Fork	10/26/99	- -	.046	06/08/00	1135	.290	08/16/00	1400	.126	10/04/00	1045	.105
MT73	Toney Fork	10/26/99	1540	.087	06/08/00	1215	.261	08/16/00	1505	.204	10/04/00	1130	.132
MT74	Unnamed tributary to Toney Fork	10/26/99	1335	.001	06/08/00	1235	.026	08/16/00	1525	.029	10/04/00	1210	.027
MT76	Reeds Branch	10/26/99	1240	.069	06/08/00	1250	.368	08/16/00	1550	.247	10/04/00	1250	.134
MT78	Raines Fork	- -	- -	- -	06/08/00	- -	0	08/22/00	- -	0	10/05/00	1315	0
MT79	Davis Fork	10/28/99	- -	.004	06/08/00	1000	.411	08/22/00	1210	.181	10/24/00	1105	.065
MT80	Lem Fork	10/28/99	- -	.012	06/08/00	1030	.359	08/22/00	1045	.092	10/27/00	1350	.018

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
MT82	Unnamed tributary to Sycamore Creek	10/28/99	--	0	06/08/00	--	0	08/22/00	--	0	10/05/00	1245	0
MT83	Unnamed tributary to Sycamore Creek	10/28/99	--	0	--	--	--	--	--	--	10/05/00	1111	.035
MT84	Sycamore Creek	10/28/99	--	0	--	--	--	--	--	--	10/05/00	1130	0
Mud River Basin													
MT03	Lukey Fork	10/26/99	--	.014	06/06/00	1350	.194	08/17/00	1550	.103	08/31/00	1045	.015
MT08	Sally Fork of Ballard Fork	10/25/99	--	.004	06/06/00	--	.006	08/17/00	1353	.009	09/06/00	1220	.016
MT09B	Sally Fork of Ballard Fork	10/25/99	1610	.008	06/06/00	1230	.016	08/17/00	1442	.099	09/06/00	1145	.008
MT10B	Ballard Fork	10/25/99	1500	.059	06/06/00	1130	.186	08/17/00	1131	.323	09/06/00	1112	.195
MT11B	Left Fork of Ballard Fork	10/25/99	1438	.075	06/08/00	1115	.093	08/17/00	--	.109	--	--	--
MT12	Unnamed tributary to Ballard Fork	10/25/99	1336	.004	06/08/00	1100	.007	08/17/00	1155	.024	09/06/00	1015	.008
MT13	Spring Branch of Ballard Fork	10/25/99	1125	.004	06/06/00	1030	.110	08/17/00	--	.073	10/12/00	1205	.007
MT14	Ballard Fork	10/25/99	1000	.375	06/06/00	0930	.781	08/17/00	1000	.082	9/13/00	1405	.435
MT16B	Unnamed tributary to Stanley Fork	10/25/99	--	.414	06/06/00	1500	.719	08/17/00	1834	1.26	09/06/00	1415	1.23
MT18	Sugartree Branch	10/25/99	--	.376	06/06/00	1600	.672	08/17/00	1652	1.62	9/28/00	1237	.622
MT20B	Sugartree Branch	10/25/99	--	.266	06/06/00	1535	.612	08/17/00	1709	1.28	10/05/00	1642	.541

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
Spruce Fork Basin													
MT25B	Rockhouse Creek	11/01/99	1545	0.089	06/07/00	1555	1.10	08/17/00	1730	1.81	10/13/00	1400	0.641
MT26	Beech Creek	11/09/99	1050	.413	06/07/00	1140	.055	08/17/00	1030	4.97	10/03/00	1130	.010
MT27	Unnamed tributary to Beech Creek	11/09/99	- -	<.001	06/07/00	1105	1.63	08/17/00	1115	.277	10/03/00	1055	1.46
MT29B	Unnamed tributary to Beech Creek	11/09/99	1100	.109	06/07/00	0945	.333	08/17/00	1425	.611	10/03/00	1315	.165
MT30B	Unnamed tributary to Beech Creek	11/09/99	1138	.069	06/07/00	1220	.245	08/17/00	1450	.492	10/03/00	1240	.163
MT31B	Unnamed tributary to Beech Creek	11/09/99	- -	.042	06/07/00	- -	.188	08/17/00	1515	.372	10/03/00	1230	.191
MT33B	Unnamed tributary to Beech Creek	11/09/99	- -	.015	06/07/00	1355	.046	08/17/00	1600	.039	10/03/00	1415	.015
MT36B	Hurricane Branch	11/09/99	1340	.172	06/07/00	1455	.320	08/17/00	1645	.658	10/03/00	1500	.315
MT37	White Oak Branch	11/01/99	1240	.005	06/07/00	1225	.023	08/21/00	1610	.050	10/03/00	1451	.023
MT38	Unnamed tributary to White Oak Branch	11/01/99	1300	0	06/07/00	1240	.035	08/21/00	1600	.057	10/13/00	1015	.026
MT39	White Oak Branch	11/01/99	1405	.014	06/07/00	1315	.057	08/21/00	1510	.246	10/13/00	1100	.063
MT41	Oldhouse Branch	11/01/99	1005	.024	06/07/00	1050	.216	08/21/00	1250	.195	10/03/00	1203	.157
MT42	Oldhouse Branch	11/01/99	1100	.010	06/07/00	1110	.190	08/21/00	1330	.245	10/03/00	1110	.138
MT43	Pigeonroost Branch	11/09/99	1330	.081	06/07/00	0950	.426	08/17/00	1245	.778	10/13/00	1150	.203

Table 5. Low-streamflow measurements at small-stream sampling sites in the coal-mining region of southern West Virginia—Continued

[--, no value, <, less than]

Station number	Stream name	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second	Date	Time, in hours	Discharge, in cubic feet per second
MT44	Unnamed tributary to Pigeonroost Branch	11/09/99	1335	0.003	06/07/00	1000	0.090	08/17/00	1315	0.402	10/13/00	1210	0.047
Twentymile Creek Basin													
MT87	Neff Fork	11/10/99	1345	.402	06/06/00	1912	3.33	08/21/00	1253	.704	11/09/00	1155	.448
MT88	Unnamed tributary to Neff Fork	11/10/99	1340	.089	06/06/00	1903	.30	08/16/00	- -	.193	11/09/00	1130	.064
MT89B	Unnamed tributary to Neff Fork	11/10/99	1450	.056	06/06/00	1816	.420	08/16/00	1357	.232	10/04/00	1527	.135
MT90	Neff Fork	11/10/99	1455	.201	06/06/00	1829	1.60	08/16/00	1428	.478	11/09/00	1055	.286
MT91	Rader Fork	11/10/99	1235	.358	06/06/00	1941	4.84	08/21/00	1237	.667	11/09/00	1235	.267
MT92	Unnamed tributary to Radar Fork	11/10/99	1230	.089	06/06/00	1634	.510	08/21/00	1402	.061	10/04/00	1620	.050
MT93	Laurel Run	11/10/99	1125	.018	06/06/00	1605	1.26	08/21/00	1524	.285	10/04/00	1728	.213
MT94	Rader Fork	11/10/99	1135	.077	06/06/00	1542	2.07	08/21/00	1449	.302	10/04/00	1700	.390
MT95	Neil Branch	10/29/99	1150	.002	06/06/00	1016	.670	08/16/00	1155	.735	10/04/00	1238	.353
MT96	Unnamed tributary to Neil Branch	10/29/99	1315	.0002	06/06/00	1122	.044	08/16/00	1105	.196	10/04/00	1139	.351
MT97	Neil Branch	10/29/99	1355	.180	06/06/00	1131	.510	08/16/00	1130	.803	10/04/00	1046	.031

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia

[--, no value]

Day	December			January			February			March		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	--	--	--	12.5	9.0	10.8	8.2	6.6	7.5	13.7	10.9	12.2
2	--	--	--	13.3	10.9	12.0	9.0	6.6	7.5	13.3	10.2	11.5
3	--	--	--	14.1	12.5	13.2	9.8	6.6	8.1	12.1	9.4	10.6
4	--	--	--	13.3	9.8	12.2	9.4	7.8	8.3	13.3	10.2	11.3
5	--	--	--	10.2	7.0	9.6	9.0	6.6	7.9	14.4	9.8	11.4
6	--	--	--	10.6	8.2	9.1	9.4	6.6	7.7	15.2	10.2	12.0
7	--	--	--	10.6	8.6	9.4	10.6	7.0	8.3	15.6	10.2	12.3
8	--	--	--	10.9	7.4	9.2	12.5	6.6	8.1	15.9	10.9	12.9
9	--	--	--	11.7	9.4	10.5	10.9	7.0	8.5	15.6	12.0	13.3
10	--	--	--	12.1	9.8	10.9	11.7	7.8	9.5	14.4	10.6	12.3
11	--	--	--	10.9	9.0	10.4	10.9	9.4	10.4	12.1	10.2	11.4
12	--	--	--	11.3	8.2	9.7	9.4	7.8	8.9	11.7	9.7	10.3
13	--	--	--	11.7	8.6	10.5	11.7	8.2	10.2	12.5	9.0	10.5
14	--	--	--	8.6	7.0	7.6	11.0	7.8	9.8	14.1	9.8	11.3
15	--	--	--	10.2	6.6	8.4	12.1	10.6	11.1	15.2	10.2	12.3
16	--	--	--	11.7	8.6	10.6	13.3	10.6	11.9	13.3	12.1	12.6
17	--	--	--	8.6	7.0	7.8	11.7	9.8	10.8	12.1	9.4	10.8
18	--	--	--	8.6	7.4	8.1	12.9	9.4	11.6	12.9	8.6	10.5
19	--	--	--	9.8	8.2	8.7	12.1	9.4	11.3	13.3	10.6	11.7
20	--	--	--	8.6	7.0	8.1	12.1	11.7	11.9	12.9	11.3	11.9
21	--	--	--	7.4	5.3	6.5	12.9	10.9	11.6	12.5	10.9	11.8
22	--	--	--	7.4	4.9	6.3	12.9	10.9	11.9	14.8	10.9	12.4
23	10.9	9.4	10.2	9.4	7.4	8.5	14.1	12.1	12.9	15.9	10.6	12.6
24	10.2	9.0	9.8	8.6	7.0	8.2	14.1	12.1	13.0	16.7	10.9	13.1
25	9.4	7.8	8.5	7.4	5.3	6.3	15.2	12.1	13.2	16.3	12.5	13.8
26	10.2	8.2	9.5	7.8	6.2	6.8	15.2	12.1	13.3	--	--	--
27	10.2	9.4	9.7	6.6	4.1	5.3	13.7	12.1	13.0	14.1	10.9	12.1
28	9.4	9.0	9.2	7.0	3.3	4.8	13.7	10.6	11.7	12.9	10.6	11.3
29	10.6	9.4	9.7	8.6	4.9	6.5	14.1	9.8	11.3	15.2	10.2	12.0
30	11.7	9.4	10.3	8.2	7.0	7.7	--	--	--	15.6	10.2	12.1
31	11.7	9.4	10.5	8.2	6.6	7.2	--	--	--	15.6	9.4	11.9
Month	--	--	--	14.1	3.3	8.7	15.2	6.6	10.4	--	--	--

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia—Continued

[--, no value]

Day	April			May			June			July		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	15.9	9.4	12.2	17.4	11.7	13.9	16.7	14.1	15.0	16.7	14.1	15.1
2	14.1	12.5	13.3	17.4	12.5	14.6	17.4	14.1	15.2	17.1	14.1	15.2
3	15.6	12.9	13.9	17.8	11.7	14.3	16.3	14.4	14.9	17.1	14.4	15.4
4	13.3	11.3	12.1	17.1	13.7	14.8	16.7	12.9	14.5	16.3	15.2	15.7
5	14.8	10.9	12.3	17.1	13.3	14.9	17.1	13.7	14.8	15.9	15.2	15.4
6	15.6	11.7	13.2	17.1	13.3	15.0	15.2	13.7	14.1	17.1	15.2	15.5
7	16.7	12.1	13.8	18.6	13.7	15.3	17.1	12.1	14.1	17.4	14.8	15.7
8	13.3	10.8	12.0	18.2	14.1	15.3	17.4	12.5	14.6	17.8	14.1	15.5
9	14.1	10.6	11.9	17.8	14.1	15.3	18.2	13.3	15.1	17.8	14.4	15.7
10	15.6	10.9	12.9	17.1	12.9	14.9	18.2	14.1	15.5	19.8	15.2	16.6
11	13.3	12.1	12.7	17.4	12.1	14.3	18.6	14.4	15.9	18.6	15.2	16.1
12	12.9	10.6	11.9	--	--	--	17.8	14.8	16.0	16.7	15.2	15.6
13	16.3	10.2	12.0	17.4	14.4	15.4	18.6	14.8	16.1	16.3	14.8	15.4
14	17.1	10.9	13.3	17.1	12.5	14.2	18.2	14.8	16.1	18.6	14.8	15.9
15	15.9	12.5	14.0	16.3	11.7	13.5	17.1	14.8	15.7	16.7	14.8	15.7
16	16.3	13.3	14.3	16.7	11.3	13.5	17.8	14.8	15.7	16.3	14.8	15.2
17	15.6	12.9	13.8	17.1	13.3	14.4	17.5	15.2	15.9	16.7	14.8	15.4
18	12.9	12.5	12.7	17.8	13.7	15.1	19.4	15.2	16.6	16.3	14.8	15.4
19	15.6	12.1	13.3	15.9	14.4	15.0	16.1	14.8	15.2	17.1	15.2	15.6
20	15.9	11.7	13.7	15.6	14.4	14.9	15.9	14.4	14.9	16.7	14.8	15.5
21	14.1	11.7	12.9	15.9	14.1	14.7	18.0	14.4	15.5	17.1	14.4	15.5
22	12.5	11.7	12.0	16.3	13.7	14.7	20.5	14.6	16.1	17.1	14.8	15.6
23	16.3	10.9	13.0	17.1	14.1	14.9	15.6	14.1	14.6	16.7	14.4	15.3
24	13.3	11.7	12.6	16.7	14.1	15.1	16.3	14.4	14.9	15.9	14.8	15.3
25	13.7	12.1	12.6	16.7	14.4	15.0	16.3	14.4	15.0	16.7	14.4	15.4
26	15.6	11.3	12.9	16.7	12.5	14.4	16.7	14.4	15.2	17.1	14.8	15.7
27	15.9	10.9	12.9	18.2	14.1	15.0	15.4	14.8	15.0	17.8	14.8	15.9
28	15.6	11.3	13.1	17.6	14.1	14.8	15.6	14.8	15.0	17.4	15.2	15.8
29	15.6	12.1	13.4	14.4	13.7	14.0	16.7	14.8	15.3	16.7	15.2	15.8
30	17.1	11.3	13.5	16.3	13.3	14.5	16.7	14.1	15.0	17.1	15.2	16.0
31	--	--	--	16.7	13.3	14.6	--	--	--	17.1	15.6	15.9
Month	17.1	9.4	12.9	--	--	--	20.5	12.1	15.2	19.8	14.1	15.6

Table 6. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Unnamed Tributary to Ballard Fork near Mud (03202405) in the coal-mining region of southern West Virginia—Continued

[--, no value]

Day	August			September			October			November		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	17.4	15.6	16.1	17.4	15.6	16.2	15.6	12.9	14.1	13.3	9.4	10.9
2	17.4	15.2	16.1	17.4	15.6	16.3	18.6	13.3	14.5	14.1	10.2	11.7
3	17.4	15.6	16.2	17.1	15.9	16.4	17.1	14.4	15.1	14.8	12.5	13.4
4	16.7	15.6	15.9	17.1	15.6	16.1	16.7	14.4	15.2	14.1	12.5	13.5
5	17.4	15.2	16.0	16.1	15.6	15.8	17.1	14.4	15.4	12.5	10.2	11.4
6	17.1	15.2	16.1	17.1	14.4	15.5	15.6	14.8	15.2	13.3	9.0	10.8
7	18.6	15.6	16.7	17.4	14.4	15.4	14.8	12.5	13.1	14.8	12.9	13.7
8	19.0	15.6	16.8	16.7	15.2	15.7	12.9	10.2	11.6	15.2	12.5	13.7
9	18.2	15.6	16.6	17.4	15.2	16.1	12.1	10.2	11.3	15.2	14.1	14.7
10	18.2	15.6	16.5	19.4	15.6	16.4	13.7	10.6	11.6	14.1	11.7	12.5
11	16.3	15.2	15.6	17.1	15.9	16.3	14.1	10.2	11.5	12.5	11.3	11.8
12	16.3	14.8	15.3	16.7	15.6	15.9	14.4	10.2	11.7	12.5	9.4	10.9
13	16.7	14.4	15.3	17.1	15.6	16.0	14.4	10.2	11.9	12.9	10.2	11.4
14	17.1	14.4	15.4	17.1	15.2	15.9	14.8	10.9	12.3	12.5	10.6	11.4
15	17.1	14.8	15.7	16.1	14.4	15.5	15.2	12.1	13.2	11.3	9.8	10.5
16	17.4	15.2	16.0	14.9	12.9	13.9	15.6	12.1	13.6	11.3	9.0	10.1
17	16.3	14.8	15.5	15.6	12.1	13.5	15.6	14.1	14.5	11.7	9.8	10.9
18	16.3	15.6	15.8	15.6	12.9	14.2	15.6	14.1	14.8	9.8	9.0	9.4
19	17.1	15.2	15.9	16.7	14.1	15.0	14.8	11.7	13.0	9.8	8.6	9.1
20	17.1	14.8	15.8	17.1	14.4	15.3	15.2	11.3	12.8	9.8	7.8	8.8
21	17.1	14.8	15.7	16.7	14.8	15.5	15.2	12.9	13.8	8.6	7.4	8.1
22	17.4	15.2	16.0	16.3	13.3	14.6	15.9	13.7	14.5	8.6	5.8	6.8
23	--	--	--	17.1	14.8	15.6	15.9	12.9	14.2	9.4	5.8	7.2
24	16.3	15.2	15.8	16.3	15.6	15.9	15.6	13.3	14.3	10.6	6.6	8.0
25	17.1	15.6	16.0	15.9	14.8	15.1	15.6	13.7	14.7	11.7	9.0	10.3
26	17.1	15.2	16.0	14.8	13.7	14.1	16.3	14.4	15.0	11.7	10.9	11.3
27	17.4	15.6	16.2	15.6	12.5	13.8	15.9	13.3	14.4	11.3	9.4	10.7
28	17.1	15.6	16.1	15.6	12.5	13.8	14.8	13.3	14.2	10.9	8.6	9.4
29	17.4	15.2	15.9	15.9	12.9	14.2	13.7	10.2	11.8	10.9	7.4	8.9
30	17.4	14.8	16.0	15.9	12.9	14.1	12.9	9.4	10.9	9.8	9.0	9.2
31	17.4	15.2	16.1	--	--	--	13.3	9.4	10.8	--	--	--
Month	--	--	--	19.4	12.1	15.3	18.6	9.4	13.4	15.2	5.8	10.7

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia

[- - , no value]

Day	December			January			February			March		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	--	--	--	4.5	1.1	2.8	.2	-.1	.0	10.9	5.3	8.2
2	--	--	--	7.0	3.7	5.3	.7	-.1	.1	9.4	5.1	7.2
3	--	--	--	9.4	6.6	8.1	.7	-.1	.2	7.8	3.3	5.6
4	--	--	--	10.2	4.9	8.6	1.1	.2	.4	9.8	4.5	6.4
5	--	--	--	4.9	2.0	3.8	1.6	-.1	.5	10.9	3.7	6.8
6	--	--	--	3.3	.7	1.8	1.1	-.1	.3	12.5	4.9	8.1
7	--	--	--	3.7	1.1	2.0	2.8	-.1	1.0	13.7	5.3	9.0
8	--	--	--	2.8	.2	1.6	3.3	-.1	1.0	15.2	7.0	10.4
9	--	--	--	5.3	2.4	3.7	4.5	-.1	1.6	14.8	9.4	11.4
10	--	--	--	7.0	3.7	5.0	5.3	.7	2.9	12.5	7.4	9.8
11	--	--	--	6.2	3.1	4.5	5.3	3.7	4.8	9.4	7.8	8.6
12	--	--	--	4.5	1.6	3.2	3.7	2.0	2.9	7.8	4.9	6.3
13	--	--	--	6.2	2.2	4.8	6.8	2.4	4.6	8.2	3.7	5.8
14	--	--	--	2.2	.2	.7	7.0	5.3	6.4	10.2	4.5	7.0
15	--	--	--	1.8	-.1	.6	6.6	4.9	5.4	12.9	6.2	9.0
16	--	--	--	5.3	1.8	3.7	9.0	5.3	6.8	10.6	9.0	9.6
17	--	--	--	2.6	.2	.8	7.0	4.1	5.5	9.4	4.9	7.1
18	--	--	--	.7	.2	.5	9.0	5.8	7.5	8.6	3.7	6.2
19	--	--	--	2.4	.7	1.4	8.2	5.8	6.7	10.6	6.6	8.2
20	--	--	--	1.1	-.1	.8	6.6	5.8	6.0	10.2	8.2	8.9
21	--	--	--	-.1	-1.0	-.5	5.8	5.3	5.5	9.8	8.2	9.0
22	--	--	--	-.1	-1.4	-.6	7.8	4.9	6.1	12.5	7.4	9.3
23	2.8	.7	1.7	-.1	-.1	-.1	10.6	6.6	8.3	14.1	6.6	9.6
24	2.0	.2	1.1	.2	-.1	.1	10.9	7.0	8.9	15.2	7.4	10.7
25	.7	.2	.3	-.1	-.6	-.4	13.3	7.8	10.0	15.2	9.8	12.0
26	1.1	.2	.5	-.1	-.6	-.5	13.7	7.8	10.2	--	--	--
27	1.1	.2	.8	-.6	-1.9	-1.0	10.6	8.8	10.0	11.7	7.8	9.4
28	.7	.2	.6	-.1	-2.4	-1.2	10.6	5.5	7.7	10.2	7.0	8.0
29	2.0	.7	1.0	-.1	-1.0	-.5	10.6	3.7	6.6	12.5	6.2	8.5
30	3.3	.2	1.7	.2	-.1	-.1	--	--	--	13.7	6.2	9.0
31	4.5	1.8	2.7	.2	-.1	.0	--	--	--	14.1	5.3	8.9
Month	--	--	--	10.2	-2.4	1.9	13.7	-.1	4.8	--	--	--

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia—Continued

[- - , no value]

Day	April			May			June			July		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	4.8	4.9	9.3	16.3	9.0	12.4	18.9	15.5	16.8	--	--	--
2	12.9	10.6	11.6	17.1	12.5	13.9	15.5	11.6	13.6	--	--	--
3	15.6	11.3	13.1	17.4	10.2	13.4	18.6	10.9	14.8	--	--	--
4	12.1	8.2	10.2	17.4	13.7	15.0	19.8	14.8	16.9	--	--	--
5	12.5	7.4	9.4	18.2	13.7	15.6	20.9	15.9	17.7	--	--	--
6	14.4	8.6	10.8	15.6	6.2	9.6	20.9	17.1	18.1	--	--	--
7	16.3	9.4	12.2	14.1	5.3	8.9	--	--	--	19.0	17.4	18.1
8	11.3	7.8	9.8	14.8	4.9	9.3	--	--	--	17.8	15.6	16.8
9	12.1	6.6	8.8	12.9	10.6	11.6	--	--	--	18.2	15.9	17.1
10	14.4	7.8	10.5	15.6	11.3	13.1	--	--	--	20.2	17.4	18.3
11	11.3	9.4	10.3	12.1	8.6	10.3	--	--	--	18.6	17.8	18.2
12	--	--	--	--	--	--	--	--	--	19.4	17.4	18.4
13	--	--	--	19.0	16.7	17.4	--	--	--	18.6	17.1	18.0
14	16.7	7.4	11.2	17.3	12.5	14.5	--	--	--	18.6	17.1	18.0
15	15.9	10.6	12.7	15.2	10.2	12.5	--	--	--	18.6	16.3	17.8
16	15.9	11.7	13.5	14.8	9.8	12.1	--	--	--	--	--	--
17	15.6	11.7	13.0	15.9	12.5	13.6	--	--	--	--	--	--
18	12.1	10.6	11.1	18.2	14.1	15.3	--	--	--	--	--	--
19	14.4	10.6	11.6	17.4	15.6	16.3	--	--	--	--	--	--
20	15.9	9.4	12.6	17.0	15.9	16.2	--	--	--	--	--	--
21	13.7	9.8	11.7	16.7	14.8	15.6	--	--	--	--	--	--
22	9.8	9.0	9.5	16.3	14.8	15.4	--	--	--	--	--	--
23	15.2	7.8	11.0	16.3	14.4	15.2	--	--	--	--	--	--
24	11.3	9.4	10.6	18.2	14.8	16.1	--	--	--	--	--	--
25	11.7	10.2	10.7	17.7	16.3	16.8	--	--	--	--	--	--
26	13.7	8.6	10.7	17.0	12.9	15.0	--	--	--	19.8	18.6	19.2
27	14.1	7.8	10.6	16.7	14.8	15.4	--	--	--	19.0	18.2	18.5
28	13.7	8.6	11.0	15.7	14.4	14.8	--	--	--	19.0	17.8	18.3
29	14.1	9.8	11.6	14.8	13.7	14.1	--	--	--	19.0	18.2	18.6
30	15.6	8.6	11.6	18.2	13.7	15.4	--	--	--	20.5	18.6	19.5
31	--	--	--	19.4	15.6	17.1	--	--	--	20.2	19.0	19.4
Month	--	--	--	--	--	--	--	--	--	--	--	--

Table 7. Maximum, minimum, and mean water temperature in degrees Celsius, December 1999 through November 2000, at Spring Branch near Mud (03202410) in the coal-mining region of southern West Virginia—Continued

[- - , no value]

Day	August			September			October			November		
	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean	Maxi-mum	Mini-mum	Mean
1	20.9	19.0	19.9	20.9	18.6	19.2	14.4	14.1	14.2	10.2	8.2	9.2
2	19.8	18.2	19.0	20.5	19.0	19.6	15.9	14.1	14.4	10.9	8.2	9.4
3	19.4	17.4	18.5	20.5	19.4	19.9	15.6	14.1	14.6	11.7	10.2	10.8
4	18.6	16.7	17.8	20.9	19.4	19.8	15.6	14.1	14.8	11.7	10.9	11.3
5	18.6	17.1	17.7	20.3	18.2	19.0	15.6	14.4	15.0	11.0	8.6	9.5
6	18.6	17.1	17.9	18.6	16.3	17.4	15.3	14.8	15.1	10.2	7.0	8.4
7	19.0	17.4	18.5	18.6	15.9	16.9	14.8	12.5	13.2	11.3	10.2	10.7
8	19.4	17.1	18.3	18.2	17.1	17.6	12.6	10.6	11.6	12.1	10.6	11.2
9	19.0	17.4	18.5	18.2	17.4	17.9	11.4	10.2	10.9	12.8	11.7	12.0
10	19.8	18.2	18.9	20.2	17.8	18.2	11.7	10.6	11.0	12.9	9.0	10.6
11	19.4	17.1	18.1	19.1	18.2	18.7	11.7	9.4	10.5	10.2	9.0	9.4
12	19.0	16.3	17.8	19.0	18.6	18.7	11.7	9.0	10.1	10.2	7.4	8.7
13	19.0	16.7	17.9	19.0	18.2	18.6	11.3	9.0	10.1	10.6	8.2	9.1
14	19.8	17.4	18.4	18.6	17.8	18.1	11.7	9.4	10.3	9.8	8.2	8.9
15	--	--	--	18.6	17.1	17.7	11.7	10.2	10.9	9.0	8.2	8.4
16	--	--	--	17.1	15.6	16.2	12.1	10.6	11.3	9.4	7.8	8.4
17	--	--	--	15.9	14.8	15.4	12.9	12.1	12.3	9.4	7.4	8.6
18	--	--	--	15.9	15.2	15.5	14.4	12.5	13.5	7.4	7.0	7.2
19	--	--	--	15.9	15.6	15.7	13.0	10.9	11.8	7.8	7.0	7.4
20	--	--	--	15.9	15.2	15.6	12.5	10.6	11.5	7.4	6.6	7.0
21	--	--	--	15.9	15.6	15.7	12.9	11.3	12.0	6.7	5.8	6.3
22	--	--	--	15.6	14.8	15.3	13.3	12.5	12.7	5.8	4.5	5.1
23	--	--	--	15.9	15.6	15.7	13.3	12.1	12.7	6.2	4.5	5.4
24	19.4	18.2	18.7	16.3	15.9	16.1	13.3	12.5	12.9	7.0	4.9	5.7
25	20.5	18.6	19.2	16.3	14.8	15.8	13.7	12.9	13.3	7.4	6.2	6.6
26	19.9	18.2	19.0	15.2	14.1	14.4	14.1	13.3	13.7	7.0	7.0	7.0
27	20.5	18.2	19.1	14.4	13.3	13.8	14.1	12.9	13.5	7.4	6.2	7.0
28	19.9	18.6	19.1	14.4	13.3	13.8	14.1	12.9	13.5	7.4	5.3	6.3
29	20.2	17.4	18.5	14.8	13.7	14.1	13.4	10.6	11.3	7.4	5.3	6.3
30	19.8	17.4	18.6	14.4	13.7	14.1	10.9	9.0	10.0	6.7	5.8	6.3
31	19.4	18.2	18.8	--	--	--	10.6	8.6	9.5	--	--	--
Month	--	--	--	20.9	13.3	16.8	15.9	8.6	12.3	12.9	4.5	8.3